

Efficacy of Residual and Non-Residual Herbicides Used in Cotton Production Systems When Applied with Glyphosate, Glufosinate, or MSMA

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Field experiments were conducted to evaluate weed control provided by glyphosate, glufosinate, and MSMA applied alone or in mixture with residual and nonresidual last application (LAYBY) herbicides. Herbicide treatments included glyphosate early postemergence (EPOST) alone or followed by glyphosate, glufosinate, or MSMA late-postemergence (LPOST) alone or tank-mixed with one of the following LAYBY herbicides: carfentrazone-ethyl at 0.3 kg ai/ha, diuron at 1.12 kg ai/ha, flumioxazin at 0.07 kg ai/ha, fluometuron at 1.12 kg ai/ha, lactofen at 0.84 kg ai/ha, linuron at 0.56 kg ai/ha, oxyfluorfen at 1.12 kg ai/ha, prometryn at 1.12 kg ai/ha, or prometryn + trifloxysulfuron at 1.12 kg ai/ha + 10 g ai/ha. Residual herbicides were also applied alone LPOST. Weeds evaluated included barnyardgrass, broadleaf signalgrass, coffee senna, entireleaf morningglory, hemp sesbania, ivyleaf morningglory, johnsongrass, large crabgrass, Palmer amaranth, pitted morningglory, prickly sida, redroot pigweed, sicklepod, smooth pigweed, spiny amaranth, and velvetleaf. Treatments containing MSMA provided lower average weed control compared to those containing glyphosate or glufosinate, and residual herbicides applied alone provided inadequate weed control compared to mixtures containing a nonresidual herbicide. Across 315 of 567 comparisons (55%), when a LAYBY herbicide was added, weed control increased. The most difficult to control weed species at all locations was pitted morningglory. Barnyardgrass and hemp sesbania at the Mississippi location and hemp sesbania at the Louisiana location were collectively difficult to control across all treatments as well.

Nomenclature: carfentrazone-ethyl; diuron; flumioxazin; fluometuron; glufosinate; glyphosate; lactofen; linuron; MSMA; oxyfluorfen; prometryn; trifloxysulfuron; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. ECHCG; broadleaf signalgrass, *Brachiaria platyphylla* (Griseb.) Nash BRAPP; coffee senna, *Cassia occidentalis* L. CASOB; entireleaf morningglory, *Ipomoea hederacea* var. *integriscula* Grey IPOHG; hemp sesbania, *Sesbania exaltata* (Raf.) Rydb. ex A. W. Hill SEBEX; ivyleaf morningglory, *Ipomoea hederacea* (L.) Jacq IPOHE; johnsongrass, *Sorghum halepense* L. Pers. SORHA; large crabgrass, *Digitaria sanguinalis* (L.) Scop. DIGSA; Palmer amaranth, *Amaranthus palmeri* L. AMAPA; pitted morningglory, *Ipomoea lacunosa* L. IPOLA; prickly sida, *Sida spinosa* L. SIDSP; redroot pigweed, *Amaranthus retroflexus* L. AMARE; sicklepod, *Senna obtusifolia* (L.) Irwin & Barnaby CASOB; smooth pigweed, *Amaranthus hybridus* L. AMACH; spiny amaranth, *Amaranthus spinosus* L. AMASP; velvetleaf, *Abutilon theophrasti* Medik. ABUTH; cotton, *Gossypium hirsutum* L.

Key words: LAYBY herbicide application, weed control.

Prior to the advent of glyphosate-resistant cotton, a typical cotton weed management system in the Southeast included a pre-emergence and/or multiple postemergence (POST) herbicide applications (Burke et al. 2005a). In 2005, glyphosate-resistant cotton cultivars were planted on greater than 95% of the cotton hectareage in the Southeast (B. Brecke, University of Florida; S. Culpepper, University of Georgia; K. Edminsten, North Carolina State University; J. Norsworthy, Clemson University; D. Monks, Auburn University, personal communications). Prior to the release of Roundup Ready Flex® cotton varieties, glyphosate label restrictions did not allow over-the-top applications of glyphosate on greater than four-leaf cotton (Anonymous 1999). Because of this restriction, most cotton growers in the Southeast utilized POST-directed spray applications, with the LAYBY often including a residual herbicide (Burke et al. 2005a; Jordan et al. 1997b; Price et al. 2004; Tingle and Chandler 2004).

The development of glyphosate-resistant cotton cultivars and new herbicides registered for POST application over-the-top of cotton has allowed growers to utilize total POST weed management systems that are conducive to high-residue reduced-tillage systems, which are increasing in adoption in cotton production areas of the United States (CTIC 2004). With the development of extended application windows in recently released Liberty Link® (glufosinate-resistant) and Roundup Ready Flex® (glyphosate-resistant) cotton cultivars, growers may be more likely to utilize these nonresidual herbicides season-long without the use of residual herbicides. Unfortunately, neither herbicide effectively controls all weeds, nor do they provide residual weed control (Coetzer et al. 2002; Tharp and Kells 2002). Prevalent weed species for which glyphosate (with one application) provides marginal or no control include bermudagrass [*Cynodon dactylon* (L.) Pers.], common milkweed (*Asclepias syriaca* L.), common ragweed (*Ambrosia artemisiifolia* L.), cutleaf eveningprimrose (*Oenothera laciniata* Hill), Florida pusley (*Richardia scabra* L.), hemp dogbane (*Apocynum cannabinum* L.), hemp sesbania, *Ipomoea* species, horsenettle (*Solanum carolinense* L.), tropical spiderwort (*Commelina benghalensis* L.), trumpet creeper (*Campsis radicans* L.), and velvetleaf (Bradley et al. 2004; Culpepper et al. 2004; Culpepper et al. 2005; Jordan et al. 1997b; Kapusta et al. 1994; Koger and Reddy 2005; Koger et al. 2005; Norsworthy and Oliver 2002). Prevalent weed

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species for which glufosinate (with one application) provides marginal or no control include common ragweed, Florida pusley, giant foxtail (*Setaria faberi* L.), goosegrass [*Echinochloa indica* (L.) Gaertn.], Palmer amaranth, silverleaf nightshade (*Solanum elaeagnifolium* Cav.), southern crabgrass [*Digitaria ciliaris* (Retz.) Koel.], and spreading dayflower (*Commelina diffusa* Burm. f.) (Barker et al. 2005; Burke et al. 2005b; Burnes et al. 2003; Corbett et al. 2004; Lanclos et al. 2002; Murdock et al. 2003; Sharp and Kells 2002; York et al. 2002).

The exclusion of residual herbicides at LAYBY application allows late-season weed interference which may be detrimental to cotton yield and cotton lint quality (Reeves et al. 2005; Tingle and Chandler 2004). A residual herbicide applied LAYBY in mixture with glufosinate, glyphosate, or MSMA could minimize late-season weed competition (Barker et al. 2005; Burke et al. 2005b; Tingle and Chandler 2004). Additionally, growers risk promoting herbicide resistance or weed spectrum shifts to species not controlled by glufosinate or glyphosate in their respective systems (Culpepper et al. 2005; Martinez-Ghersa et al. 2003; Reddy 2004).

At the time this research was initiated, commonly used labeled residual and nonresidual herbicides applied as a post-directed spray in cotton included carfentrazone-ethyl, cyanazine, diuron, flumioxazin, fluometuron, lactofen, linuron, oxyfluorfen, prometryn, and a packaged mixture of prometryn and trifloxysulfuron-sodium. MSMA is a common herbicide used in conjunction with residual LAYBY herbicides (Corbett et al. 2002; Jordan et al. 1997a). Prometryn plus MSMA applied at LAYBY has been shown to increase control of common ragweed, entireleaf morningglory, jimsonweed (*Datura stramonium* L.), pitted morningglory, smooth pigweed, tall morningglory [*Ipomoea purpurea* (L.) Roth] and yellow nutsedge (*Cyperus esculentus* L.) compared to systems that only included pre-emergence plus POST herbicide applications (Burke and Wilcut 2004; Porterfield et al. 2002). However, compared to POST-only systems, prometryn plus MSMA applied at LAYBY did not increase control of barnyardgrass, large crabgrass, pitted morningglory, or Texas panicum (*Panicum texanum* Buckl.) compared to glyphosate applied LAYBY alone (Faircloth et al. 2001). MSMA has been shown to increase control of entireleaf morningglory, palmleaf morningglory (*Ipomoea wrightii* Gray), pitted morningglory, tall morningglory, and sicklepod when mixed with diuron, fluometuron, lactofen, or oxyfluorfen while providing little control of hemp sesbania or velvetleaf (Jordan et al. 1997a).

While some research has evaluated weed control following residual LAYBY herbicide applications, few experiments have compared weed control following different LAYBY tank-mixes that include glyphosate, glufosinate, or MSMA. Therefore, our objective was to evaluate weed control provided by glyphosate, glufosinate, and MSMA applied alone or mixed with different LAYBY herbicides.

Materials and Methods

Field experiments were conducted in summer 2003 at the United States Department of Agriculture (USDA) Southern

Weed Science Research Farm, Stoneville, MS; the Alabama Agricultural Experiment Station's E.V. Smith Research and Extension Center, Shorter, AL; the Louisiana State University AgCenter Northeast Research Station, St. Josephs, LA; and the Kinston and Rocky Mount Research and Extension Centers, NC. The soils were a Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualfs) at Stoneville, a Dothan fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudult) at Shorter, a Mhoon silt loam soil (fine-silty, mixed nonacid, thermic Typic Fluvaquents) at St. Josephs, and a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) at both Kinston and Rocky Mount.

The experimental design was a randomized complete block design with three replications of each treatment at both NC locations and four replications at the MS, AL, and LA locations. Herbicide treatments included glyphosate EPOST alone or followed by 1) glyphosate, 2) glufosinate, or 3) MSMA LPOST alone or tank-mixed with one of the following layby herbicides: 4–7) carfentrazone-ethyl at 0.3 kg ai/ha, 8–11) diuron at 1.12 kg ai/ha, 12–15) flumioxazin at 0.07 kg ai/ha, 16–19) fluometuron at 1.12 kg ai/ha, 20–23) lactofen at 0.84 kg ai/ha, 24–27) linuron at 0.56 kg ai/ha, 28–31) oxyfluorfen at 1.12 kg ai/ha, 32–35) prometryn at 1.12 kg ai/ha, or 36–39) prometryn + trifloxysulfuron at 1.12 kg ai/ha + 10 g ai/ha. LAYBY herbicides were also applied alone LPOST. EPOST treatments were broadcast applied when weeds were between one and two-leaf growth stage and LPOST treatments were broadcast applied when weeds were between 8 and 10 cm tall utilizing a compressed CO₂ backpack sprayer delivering 140 L/ha at 147 kPa. A nonionic surfactant¹ (NIS) at 0.25% (v/v) or crop oil concentrate² (COC) at 1.67% (v/v) was included in the LAYBY herbicide treatments depending on label instructions.

Weed control was estimated by visual ratings (0% = no control, 100% = complete control) at 7, 14, and 21 d after LPOST application. All weed species present were evaluated for control as a reduction in total aboveground biomass resulting from both reduced emergence and growth. Only ratings for 21 d after LPOST application are reported.

All data were subjected to ANOVA using the general linear models procedure in SAS (SAS 1998) to evaluate herbicide treatments. Treatments were considered fixed effects while location effects were considered random. Means were separated using Fisher's protected LSD test at $P = 0.1$.

Results and Discussion

Analysis revealed a location by treatment interaction; therefore, results are presented by location.

Alabama. Analysis revealed large variance within treatments, likely due to drought conditions present at herbicide application. Thus, data from Alabama is not presented. It is important to note that none of the 40 herbicide treatments evaluated performed consistently under dry soil moisture conditions. The lack of performance of various residual and nonresidual herbicides under dry soil conditions is widely documented by others (Bruce et al. 1996; Harrison et al. 1996).

Table 1. Visual estimates of barnyardgrass (ECHCG), coffee senna (CASOB), hemp sesbania (SEBEX), ivyleaf morningglory (IPOHE), johnsongrass (SORHA), pitted morningglory (IPOLA), prickly sida (SIDSP), and velvetleaf (ABUTH) control 3 wk after LPOST herbicide application in Mississippi.

Herbicide treatments ^a										
EPOST ^b	LPOST		Mississippi							
	Nonresidual	Residual	ECHCG	CASOB	SEBEX	IPOHE	SORHA	IPOLA	SIDSP	ABUTH
			% control							
Nontreated			0	0	0	0	0	0	0	0
Glyph ^c			0	0	20	13	0	13	20	20
Glyph	Glyph		57	63	48	18	79	28	82	85
Glyph	Glyph	flumio	33	76	83	46	56	56	88	76
Glyph	Glyph	promet	48	78	83	43	73	63	78	63
Glyph	Glyph	fluomet	83	83	46	66	92	53	86	66
Glyph	Glyph	lactofen	13	76	92	56	81	63	86	71
Glyph	Glyph	oxyflu	58	78	83	78	81	69	92	92
Glyph	Glyph	diuron	63	78	83	63	83	65	83	83
Glyph	Glyph	linuron	73	76	92	36	86	43	92	91
Glyph	Glyph	carfen	3	92	92	86	73	92	92	84
Glyph	Glyph	pro + tri	23	78	85	48	78	63	91	73
Glyph	Gluf		41	71	75	21	41	74	76	26
Glyph	Gluf	flumio	5	64	75	41	36	60	89	61
Glyph	Gluf	promet	48	74	91	84	61	79	91	84
Glyph	Gluf	fluomet	54	71	70	48	38	71	60	63
Glyph	Gluf	lactofen	19	76	94	75	63	71	92	81
Glyph	Gluf	oxyflu	56	85	90	85	83	90	90	84
Glyph	Gluf	diuron	39	76	66	63	48	76	63	63
Glyph	Gluf	linuron	64	61	86	71	68	81	85	78
Glyph	Gluf	carfen	25	63	83	74	41	76	75	86
Glyph	Gluf	pro + tri	58	75	91	84	28	64	83	78
Glyph	MSMA		6	58	0	14	15	48	28	0
Glyph	MSMA	flumio	10	59	70	60	41	68	61	74
Glyph	MSMA	promet	24	56	74	39	44	70	71	49
Glyph	MSMA	fluomet	15	61	30	25	34	61	3	33
Glyph	MSMA	lactofen	20	71	85	71	64	86	85	67
Glyph	MSMA	oxyflu	43	78	94	88	81	81	94	90
Glyph	MSMA	diuron	45	69	56	51	33	68	39	54
Glyph	MSMA	linuron	39	71	87	66	59	73	87	86
Glyph	MSMA	carfen	0	64	89	88	34	89	89	89
Glyph	MSMA	pro + tri	34	68	74	41	43	74	44	43
Glyph		flumio	3	48	44	14	0	4	54	44
Glyph		promet	0	29	54	14	0	24	59	53.8
Glyph		fluomet	39	63	40	63	35	63	61	0
Glyph		lactofen	0	19	86	9	9	23	83	53
Glyph		oxyflu	0	54	74	39	9	63	79	63
Glyph		diuron	0	19	10	4	20	14	6	24
Glyph		linuron	0	34	84	0	0	0	58	79
Glyph		carfen	0	4	80	53	0	53	80	85
Glyph		pro + tri	0	51	51	3	38	45	38	38
LSD (0.1) ^d			21	8	16	18	13	9	16	16

^a Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included carfentrazone-ethyl at 0.3 kg ai/ha, flumioxazin (0.07 kg ai/ha), prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), lactofen (0.84 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), diuron (1.12 kg ai/ha), linuron (0.56 kg ai/ha), and prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha).

^b EPOST treatments were applied over-the-top of weeds in the cotyledon to two-leaf growth stage; LPOST treatments were applied over-the-top of four- to twelve-leaf weeds.

^c Abbreviations: glyph, glyphosate; gluf, glufosinate; flumio, flumioxazin; promet, prometryn; flomet, flometuron; oxyflu, oxyfluorfen; carfen, carfentrazone-ethyl; pro + tri, prepackaged mixture of prometryn and trifloxysulfuron-sodium.

^d Means within a column are separated according to LSD value at P = 0.1.

Mississippi. Glyphosate or glufosinate applied LPOST following glyphosate EPOST (two applications) improved barnyardgrass, coffee senna, hemp sesbania, johnsongrass, and prickly sida control \geq 28 percentage points compared to glyphosate EPOST alone (one application) (Table 1). Glyphosate EPOST followed by (fb) glyphosate LPOST increased velvetleaf control 65 percentage points compared to glyphosate EPOST alone and provided 38 percentage points higher

control of johnsongrass compared to glyphosate EPOST fb glufosinate LPOST. Glyphosate EPOST fb glufosinate LPOST increased pitted morningglory control 61 percentage points compared to glyphosate EPOST alone and provided superior control of hemp sesbania compared to glyphosate EPOST fb glyphosate LPOST and glyphosate EPOST fb MSMA LPOST. Glyphosate EPOST fb MSMA LPOST provided similar coffee senna control compared to glyphosate

EPOST fb glyphosate LPOST and less control than glyphosate EPOST fb glufosinate LPOST. Additionally, glyphosate EPOST fb MSMA LPOST provided 20 percentage points higher control of pitted morningglory compared to glyphosate EPOST fb glyphosate LPOST; barnyardgrass, hemp sesbania, ivyleaf morningglory, johnsongrass, prickly sida, and velvetleaf control was lower following glyphosate EPOST fb MSMA LPOST compared to glyphosate EPOST fb glyphosate or glufosinate LPOST.

Averaged across residual herbicides, treatments containing glyphosate or glufosinate provided similar barnyardgrass, coffee senna, prickly sida, and velvetleaf control. When glyphosate was included LPOST, johnsongrass control increased ≥ 13 percentage points over treatments containing glufosinate when averaged across residual LPOST treatments. However, averaged across residual herbicides, glufosinate containing treatments provided higher ivyleaf morningglory, pitted morningglory, and hemp sesbania control compared to treatments containing glyphosate. Averaged across residual LPOST herbicides, MSMA containing treatments provided lower barnyardgrass, johnsongrass, prickly sida, and velvetleaf control, while providing higher pitted morningglory control compared to treatments containing glyphosate.

Glyphosate LPOST mixed with any of the nine residual herbicides improved barnyardgrass, coffee senna, hemp sesbania, ivyleaf, and pitted morningglory control, compared to glyphosate LPOST alone, while johnsongrass, prickly sida, and velvetleaf control did not increase. Glufosinate LPOST mixed with any of the nine residual herbicides improved coffee senna, hemp sesbania, ivyleaf morningglory, johnsongrass, pitted morningglory, prickly sida, and increased velvetleaf control compared to glufosinate LPOST alone, while barnyardgrass control did not increase. MSMA LPOST mixed with any of the nine residual herbicides improved barnyardgrass control, coffee senna, hemp sesbania, ivyleaf morningglory, johnsongrass, pitted morningglory, prickly sida, and velvetleaf increased control compared to MSMA LPOST alone. No herbicide system provided $\geq 83\%$ control averaged over the entire weed spectrum evaluated in Mississippi, illustrating the inconsistent barnyardgrass, hemp sesbania, and pitted morningglory control. The highest weed control in Mississippi was observed in systems containing a nonresidual herbicide mixed with oxyfluorfen.

North Carolina—Rocky Mount. Glyphosate, glufosinate, or MSMA applied POST following glyphosate EPOST (two applications) improved broadleaf signalgrass, entireleaf morningglory, ivyleaf morningglory, large crabgrass, and Palmer amaranth control ≥ 19 percentage points compared to glyphosate EPOST alone (one application) (Table 2). Glyphosate and glufosinate applied LPOST following glyphosate EPOST also improved pitted morningglory control ≥ 46 percentage points compared to glyphosate EPOST alone, whereas MSMA applied POST following glyphosate EPOST did not improve pitted morningglory control.

Averaged across residual POST herbicides, treatments containing glyphosate, glufosinate, or MSMA provided similar broadleaf signalgrass, ivyleaf morningglory, entireleaf morningglory, and Palmer amaranth control. Large crabgrass control was 7% higher in glufosinate containing treatments

compared to glyphosate containing treatments when averaged across residual LPOST herbicides. Averaged across residual POST herbicide treatments, MSMA containing treatments provided 9% less pitted morningglory control compared to glyphosate or glufosinate containing treatments.

Glyphosate LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, entireleaf morningglory, ivyleaf morningglory, large crabgrass, Palmer amaranth, and pitted morningglory control compared to glyphosate LPOST alone. Glufosinate LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, entireleaf morningglory, ivyleaf morningglory, large crabgrass, Palmer amaranth, and pitted morningglory control compared to glufosinate POST alone. MSMA LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, entireleaf morningglory, ivyleaf morningglory, large crabgrass, Palmer amaranth, and pitted morningglory, compared to MSMA LPOST alone. The best weed control at Rocky Mount 21 d after treatment (DAT) included a nonresidual tank mixed with fluometuron or flumioxazin. All other systems provided less than 88% control when averaged across weed species, illustrating again inconsistent pitted morningglory control.

North Carolina—Kinston. Glyphosate, glufosinate, or MSMA applied LPOST following glyphosate EPOST (two applications) improved broadleaf signalgrass and pitted morningglory control ≥ 34 and ≥ 19 percentage points respectively, compared to glyphosate EPOST alone (one application) (Table 2). Glyphosate and glufosinate applied POST following glyphosate EPOST also improved Palmer amaranth control ≥ 46 percentage points compared to glyphosate EPOST alone, whereas MSMA applied POST following glyphosate EPOST did not improve Palmer amaranth control.

Averaged across residual LPOST herbicides, treatments containing glyphosate and glufosinate provided similar Palmer amaranth and pitted morningglory control while glufosinate containing treatments provided 11% and 6% less broadleaf signalgrass control compared to glyphosate and MSMA containing treatments, respectively. Averaged across residual LPOST herbicides, treatments containing MSMA provided 6 and 7 percentage points less pitted morningglory control compared to glyphosate and glufosinate, respectively, while providing similar Palmer amaranth control compared to both glyphosate and glufosinate.

Glyphosate LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, Palmer amaranth, and pitted morningglory control compared to glyphosate LPOST alone. Glufosinate LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, Palmer amaranth, and pitted morningglory control compared to glufosinate LPOST alone. MSMA LPOST mixed with any of the nine residual herbicides improved broadleaf signalgrass, Palmer amaranth, and pitted morningglory control compared to MSMA LPOST alone. The highest weed control at Kinston 21 DAT was observed in systems containing a nonresidual herbicide mixed with carfentrazone, fluometuron, flumioxazin, or a mixture of prometryn + trifloxysulfuron. Observed weed control provided by glyphosate mixed with flumioxazin agrees with Askew et al. (2002), who reported

Table 2. Visual estimates of broadleaf signalgrass (BRAPP), entireleaf morningglory (IPOHG), ivyleaf morningglory (IPOHE), large crabgrass (DIGSA), Palmer amaranth (AMAPA), and pitted morningglory (IPOLA) control 3 wk after LPOST herbicide application in Rocky Mount, North Carolina as well as large crabgrass, Palmer amaranth, and pitted morningglory in Kinston, North Carolina.

Herbicide treatments ^a											
EPOST ^b	POST		Rocky Mount						Kinston		
	Nonresidual	Residual	BRAPP	IPOHG	IPOHE	DIGSA	AMAPA	IPOLA	DIGSA	AMAPA	IPOLA
			% control								
Nontreated			0	0	0	0	0	0	0	0	0
Glyph ^c			31	28	36	21	9	3	28	21	31
Glyph	Glyph		80	60	54	67	60	51	75	70	59
Glyph	Glyph	flumio	96	98	92	94	79	100	91	100	97
Glyph	Glyph	promet	80	84	83	72	55	69	78	79	84
Glyph	Glyph	fluomet	94	93	93	90	86	99	91	89	93
Glyph	Glyph	lactofen	83	88	81	71	62	90	80	84	89
Glyph	Glyph	oxyflu	80	82	79	70	61	60	79	74	84
Glyph	Glyph	diuron	80	77	75	71	57	62	76	70	78
Glyph	Glyph	linuron	66	72	70	65	55	40	65	62	73
Glyph	Glyph	carfen	81	97	93	99	61	96	90	92	90
Glyph	Glyph	pro + tri	76	96	91	91	68	90	83	94	94
Glyph	Gluf		77	71	69	74	55	49	74	67	50
Glyph	Gluf	flumio	97	97	99	99	77	100	87	100	97
Glyph	Gluf	promet	80	80	87	81	55	66	77	81	83
Glyph	Gluf	fluomet	93	91	95	93	88	100	89	91	91
Glyph	Gluf	lactofen	90	92	90	81	56	91	81	78	92
Glyph	Gluf	oxyflu	80	86	83	80	61	55	76	73	88
Glyph	Gluf	diuron	70	80	80	77	54	54	71	70	85
Glyph	Gluf	linuron	60	72	76	73	50	46	62	71	72
Glyph	Gluf	carfen	78	90	92	100	64	99	77	90	92
Glyph	Gluf	pro + tri	71	96	92	99	62	89	81	96	96
Glyph	MSMA		71	51	60	69	52	0	62	20	50
Glyph	MSMA	flumio	93	95	95	94	71	99	80	99	92
Glyph	MSMA	promet	91	81	80	79	47	49	75	72	79
Glyph	MSMA	fluomet	92	92	93	91	91	99	88	81	90
Glyph	MSMA	lactofen	83	80	83	78	62	60	80	80	80
Glyph	MSMA	oxyflu	74	78	76	74	60	51	69	60	75
Glyph	MSMA	diuron	66	67	72	73	51	47	69	60	66
Glyph	MSMA	linuron	60	67	67	71	47	34	61	59	68
Glyph	MSMA	carfen	78	90	94	97	63	94	76	93	92
Glyph	MSMA	pro + tri	70	91	89	97	62	92	75	98	90
Glyph		flumio	40	91	97	89	43	100	43	99	94
Glyph		promet	31	59	60	40	26	40	32	70	61
Glyph		fluomet	41	74	78	86	61	79	40	90	76
Glyph		lactofen	28	70	71	70	29	69	26	89	71
Glyph		oxyflu	29.0	51	51	50	23	41	17	65	49
Glyph		diuron	24	50	51	40	21	31	24	60	52
Glyph		linuron	21	39	42	29	14	24	24	51	41
Glyph		carfen	24	90	89	96	40	92	20	93	91
Glyph		pro + tri	29	89	90	81	39	80	21	96	90
LSD (0.1) ^d			6	5	6	6	6	6	6	6	6

^a Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included carfentrazone-ethyl at 0.3 kg ai/ha, flumioxazin (0.07 kg ai/ha), prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), lactofen (0.84 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), diuron (1.12 kg ai/ha), linuron (0.56 kg ai/ha), and prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha).

^b EPOST treatments were applied over-the-top of weeds in the cotyledon to two-leaf growth stage; LPOST treatments were applied over-the-top of four to twelve-leaf weeds.

^c Abbreviations: glyph, glyphosate; gluf, glufosinate; flumio, flumioxazin; promet, prometryn; flomet, flometuron; oxyflu, oxyfluorfen; carfen, carfentrazone-ethyl; pro + tri, prepackaged mixture of prometryn and trifloxysulfuron-sodium.

^d Means within a column are separated according to LSD value at $P = 0.1$.

increased pitted morningglory control when glyphosate was tank-mixed with flumioxazin compared to glyphosate applied alone.

Louisiana. Glyphosate, glufosinate, or MSMA applied LPOST following glyphosate EPOST (two applications) improved ivyleaf morningglory, pitted morningglory, and redroot pigweed control ≥ 42 percentage points compared to

glyphosate EPOST alone (one application) (Table 3). Glufosinate applied POST following glyphosate EPOST also improved hemp sesbania control 54 percentage points compared to glyphosate EPOST alone, whereas glyphosate and MSMA did not improve control.

Averaged across residual LPOST herbicides, treatments containing glyphosate, glufosinate, or MSMA provided

Table 3. Visual estimates of hemp sesbania (SEBEX), ivyleaf morningglory (IPOHE), pitted morningglory (IPOLA), and redroot pigweed (AMARE) control 3 wk after LPOST herbicide application in Louisiana.

Herbicide treatments ^a						
EPOST ^b	POST		Louisiana			
	Nonresidual	Residual	SEBEX	IPOHE	IPOLA	AMARE
			% control			
Nontreated			10	40	20	10
Glyph ^c			26	44	23	23
Glyph	Glyph		38	84	79	73
Glyph	Glyph	flumio	73	95	86	85
Glyph	Glyph	promet	81	95	83	94
Glyph	Glyph	fluomet	69	90	83	84
Glyph	Glyph	lactofen	78	93	73	83
Glyph	Glyph	oxyflu	80	95	83	94
Glyph	Glyph	diuron	49	93	84	79
Glyph	Glyph	linuron	70	95	80	93
Glyph	Glyph	carfen	60	91	83	91
Glyph	Glyph	pro + tri	83	93	80	94
Glyph	Gluf		80	95	86	71
Glyph	Gluf	flumio	75	92	85	57
Glyph	Gluf	promet	68	92	88	65
Glyph	Gluf	fluomet	74	93	85	78
Glyph	Gluf	lactofen	74	91	86	75
Glyph	Gluf	oxyflu	89	95	94	85
Glyph	Gluf	diuron	45	93	76	75
Glyph	Gluf	linuron	78	90	77	78
Glyph	Gluf	carfen	65	78	70	76
Glyph	Gluf	pro + tri	83	95	91	88
Glyph	MSMA		43	93	80	65
Glyph	MSMA	flumio	59	95	91	69
Glyph	MSMA	promet	54	95	91	74
Glyph	MSMA	fluomet	44	91	78	69
Glyph	MSMA	lactofen	64	94	91	76
Glyph	MSMA	oxyflu	71	95	90	83
Glyph	MSMA	diuron	49	93	79	64
Glyph	MSMA	linuron	64	84	64	63
Glyph	MSMA	carfen	64	95	90	86
Glyph	MSMA	pro + tri	73	94	89	78
Glyph		flumio	61	89	91	71
Glyph		promet	30	86	54	36
Glyph		fluomet	40	89	63	45
Glyph		lactofen	68	93	70	60
Glyph		oxyflu	41	85	50	43
Glyph		diuron	15	60	43	36
Glyph		linuron	71	88	61	39
Glyph		carfen	63	93	80	90
Glyph		pro + tri	70	89	81	78
LSD (0.1) ^d			22	14	15	19

^a Glyphosate was applied at 0.86 kg ae/ha and glufosinate was applied at 0.47 kg ai/ha in all treatments. Residual herbicides included carfentrazone-ethyl at 0.3 kg ai/ha, flumioxazin (0.07 kg ai/ha), prometryn (1.12 kg ai/ha), fluometuron (1.12 kg ai/ha), lactofen (0.84 kg ai/ha), oxyfluorfen (1.12 kg ai/ha), diuron (1.12 kg ai/ha), linuron (0.56 kg ai/ha), and prometryn + trifloxysulfuron (1.33 kg ai/ha + 12 g ai/ha).

^b EPOST treatments were applied over-the-top of weeds in the cotyledon to two-leaf growth stage; LPOST treatments were applied over-the-top of four to twelve-leaf weeds.

^c Abbreviations: glyph, glyphosate; gluf, glufosinate; flumio, flumioxazin; promet, prometryn; flomet, flometuron; oxyflu, oxyfluorfen; carfen, carfentrazone-ethyl; pro + tri, prepackaged mixture of prometryn and trifloxysulfuron-sodium.

^d Means within a column are separated according to LSD value at $P = 0.1$.

similar control of all weeds evaluated including hemp sesbania, ivyleaf morningglory, pitted morningglory, and redroot pigweed.

Glyphosate LPOST mixed with any of the nine residual herbicides improved hemp sesbania and redroot pigweed control, but did not improve ivyleaf morningglory or pitted morningglory control compared to glyphosate LPOST alone. Glufosinate LPOST mixed with any of the nine residual

herbicides did not improve weed control compared to glufosinate LPOST alone. MSMA LPOST mixed with any of the nine residual herbicides improved only redroot pigweed control in one comparison when compared to MSMA LPOST alone. No herbicide system provided $\geq 91\%$ control averaged over the entire weed spectrum evaluated in Louisiana, again illustrating the inconsistent hemp sesbania and pitted morningglory control. The highest weed control in

Louisiana 21 DAT was observed in systems containing a nonresidual herbicide mixed with carfentrazone, oxyfluorfen, prometryn, or a mixture of prometryn + trifloxysulfuron. Observed weed control provided by glyphosate mixed with prometryn + trifloxysulfuron agrees with Lee et al. (2003) who reported increased pitted morningglory and hemp sesbania control when glyphosate was tank-mixed with prometryn + trifloxysulfuron compared to glyphosate applied alone. Potential carfentrazone antagonism by glufosinate was also observed in Louisiana; observations revealed a 10 percentage point decrease in pitted morningglory control with a glufosinate–carfentrazone mixture compared to carfentrazone alone.

At all locations, pitted morningglory was consistently the most problematic weed to control. At Mississippi and Louisiana, hemp sesbania was also problematic. Across locations, glufosinate containing treatments provided the highest pitted morningglory and hemp sesbania control. When comparing weed control provided by glyphosate applied LPOST alone, including a residual herbicide increased control 53% of the time. When comparing weed control provided by glufosinate applied LPOST alone, including a residual herbicide increased control 44% of the time. When comparing weed control provided by MSMA applied LPOST alone, including a residual herbicide increased control 69% of the time, revealing that MSMA is often a less effective tank-mix partner compared to glyphosate or glufosinate; however, MSMA provides an alternative mode of action compared to glyphosate or glufosinate, an important aspect in resistance management. Overall, in 567 weed control comparisons, including a residual herbicide increased control 55% of the time.

Sources of Materials

¹ Induce® nonionic low foam wetter/spreader adjuvant containing 90% nonionic surfactant (alkylaryl polyoxyalkane ether and isopropanol), free fatty acids, and 10% water. Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

² Agridex®, 83% paraffin base petroleum oil and 17% surfactant blend. Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

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Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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